Published in final edited form as:

Physiotherapy. 2015 June ; 101(2): 147–154. doi:10.1016/j.physio.2014.07.003.

Upper extremity impairments, pain and disability in patients with diabetes mellitus

K.M. Shah^{a,*}, B.R. Clark^a, J.B. McGill^b, and M.J. Mueller^{a,c}

^aProgram in Physical Therapy, Washington University School of Medicine in St. Louis, USA

^bDivision of Endocrinology, Metabolism and Lipid Research, Department of Medicine, Washington University School of Medicine in St. Louis, USA

^cDepartment of Radiology, Washington University School of Medicine in St. Louis, USA

Abstract

Objectives—To determine the severity of, and relationships between, upper extremity impairments, pain and disability in patients with diabetes mellitus, and to compare upper extremity impairments in patients with diabetes with non-diabetic controls.

Design—Case-control, cross-sectional design.

Setting—University-based, outpatient diabetes centre and physical therapy research clinic.

Participants—Two hundred and thirty-six patients with diabetes attending an outpatient diabetes clinic completed the Shoulder Pain and Disability Index (SPADI) questionnaire. A detailed shoulder and hand examination was conducted on a subgroup of 29 volunteers with type 2 diabetes, and 27 controls matched for age, sex and body mass index.

Interventions—None.

Main outcome measures—SPADI score, passive shoulder range of motion (ROM) and strength, grip strength, hand sensation, dexterity and limited joint mobility of the hand.

Results—Sixty-three percent (149/236) of patients with diabetes reported shoulder pain and/or disability [median SPADI score 10.0 (interquartile range 0.0 to 39.6)]. Compared with the control group, the subgroup of patients with diabetes had substantial reductions in shoulder ROM, shoulder muscle strength, grip and key pinch strength ($P < 0.05$). Patients with diabetes had a greater prevalence of decreased sensation (26/27 vs 14/27) and limited joint mobility of the hand (17/27 vs 4/27) compared with the control group. Total SPADI score was negatively correlated

© 2014 Elsevier Ltd on behalf of The Chartered Society of Physiotherapy. All rights reserved.

*Corresponding author at: Program in Physical Therapy, Washington University School of Medicine in St. Louis, USA. kshamata16@gmail.com (K.M. Shah).

Ethical approval: Washington University in St. Louis Institutional Review Board.

Conflict of interest: None declared.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

($P<0.05$) with shoulder ROM ($r = -0.42$ to -0.74) and strength measures ($r = -0.44$ to -0.63) in patients with diabetes.

Conclusions—Upper extremity impairments in this sample of patients with diabetes were common, severe and related to complaints of pain and disability. Additional research is needed to understand the unique reasons for upper extremity problems in patients with diabetes, and to identify preventative treatments.

Keywords

Diabetes mellitus; Upper extremity; Shoulder; Hand

Introduction

Upper extremity musculoskeletal disorders are a common and understudied problem in patients with diabetes mellitus [1–3]. Clinical syndromes described in patients with diabetes [2,3] include, but are not limited to, shoulder adhesive capsulitis or frozen shoulder, limited joint mobility of the hand, Dupuytren's contracture and carpal tunnel syndrome. Prior reports have suggested that the prevalence of shoulder impairments is significantly higher in patients with diabetes (11 to 50%) [4–8] compared with those without diabetes (2 to 20%) [4,6–8]. Similarly, the prevalence of hand impairments is variably reported to be 8 to 75% [6,9,10] in patients with diabetes compared with 0 to 26% in those without diabetes [6,10]. A significant relationship has been found between the prevalence of shoulder and hand impairments, suggesting that they often co-exist and may have a common mechanism [1,6,11].

Limited joint mobility in diabetes is thought to be caused by non-inflammatory thickening and increased stiffness in the peri-articular structures [12]. First observed at the hand, limited joint mobility may also occur at the shoulder [4,9,13]. At the beginning, limited joint mobility of the shoulder and hand may be painless and therefore unnoticed. However, limited joint mobility may precede severe upper extremity impairments associated with pain and/or disability. The presence of limited joint mobility and associated impairments at the shoulder and hand may have a significant impact on upper extremity function in patients with diabetes.

Studies have examined shoulder [7,14–16] or hand [11,17–20] impairments in patients with diabetes, but the combined influence of shoulder and hand impairments on upper extremity pain and disability has not, to the authors' knowledge, been studied to date. A few studies have examined limited joint mobility of the shoulder and reported differences in range of motion (ROM) between patients with diabetes and those without diabetes [7,14–16], but studies of shoulder strength and upper extremity function are lacking. The aims of this study were:

- to determine the severity of upper extremity pain and disability in patients with diabetes attending an outpatient diabetes clinic. Pain and disability were estimated using the Shoulder Pain and Disability Index (SPADI) [21,22], a self-report questionnaire that has been used previously in patients with diabetes [5,7];

- to compare shoulder ROM, strength and hand function measures in subgroups of patients with diabetes and those without diabetes [matched for age, sex and body mass index (BMI)]; and
- to determine the relationship between shoulder and hand strength and joint mobility, and upper extremity pain and disability in patients with diabetes.

Understanding these outcomes and relationships should help to focus future rehabilitation research and interventions in order to reduce the severity of upper extremity impairments and disability in patients with diabetes.

Methods

Participants

A flyer containing the SPADI questionnaire, demographic information sheet, cover letter and consent form was posted to 336 patients with diabetes enrolled on the Diabetes and Research Training Center Prevention and Control Core patient database. The flyer included a section for the participants to indicate if they wished to be contacted for an upper extremity examination. The cover letter encouraged the participants to respond even if they did not have pain and/or disability. Consent was also obtained to distribute 103 questionnaires at the diabetes clinic to unselected patients with diabetes who were willing to participate in the study. In total, 236 patients completed the questionnaire (Table 1). The SPADI self-report questionnaire contains 13 items that assess pain (five items) and disability (eight items) [21,22]. Each item is scored from 0 to 10, and scores for each subgroup are averaged and converted to a percentage [22]. The total SPADI score is an average of the two subscores, and ranges from 0 to 100%; a higher score indicates more pain and disability. The SPADI questionnaire has excellent reliability, includes questions on shoulder and hand function, and is quick and easy (<5 minutes) to administer [23].

A detailed shoulder and hand evaluation was completed on: (1) a subgroup of the first 29 patients with type 2 diabetes who agreed to participate when contacted by the research team; and (2) 27 individuals without diabetes or current shoulder pain/disability, who were well matched for age, sex, weight, height, BMI and handedness ($P>0.05$; Table 2). A high effect size (Cohen's $d=0.8$) was anticipated for all key outcome variables (shoulder ROM and strength, and hand function). Calculations indicated that a sample size of 27 in each group was required to find statistical differences between the groups [statistical power level=0.8 and $\alpha=0.05$ (two tailed)]. Data from all participants in the diabetes group were used to examine the relationship between the SPADI score and upper extremity clinical measures. The control subjects were recruited from a university database of healthy volunteers. Participants in both groups were aged >35 years and did not have recent (past 6 months) shoulder injuries, known rotator cuff tears or neck pain. Information about occupation, and whether it involved overhead activities, was collected. The majority of participants in both groups were retired, and leisure-time hobbies included gardening, travel and reading. The control subjects also completed the SPADI questionnaire when they attended the clinic for their visit. All participants read and signed the consent form approved by the institutional review board.

The same physical therapist, who was not blinded to group allocation, performed the clinical examinations of both upper extremities on all participants. For all evaluation measures, an average of two trials was used for data analyses, with adequate rests between trials.

Shoulder evaluation

Shoulder ROM was measured using a 12" plastic goniometer (Baseline, Elmsford, NY, USA) and standardised methods with established reliability [24–27]. Active ROM was measured for flexion, abduction and external rotation ROM with the subject seated on a stool without a backrest [24,25]. External rotation movement was measured with the arm close to the body and the elbow bent at 90° [27]. Maximal passive ROM in the pain-free range was measured for shoulder flexion, abduction, internal rotation and external rotation with the subject in a supine position [24,26]. Arm rotation was measured with the arm abducted to 90°, and the elbow in 90° flexion and neutral rotation [25,26]. The active ROM assessment helped to 'loosen up' the joint prior to passive movement, and the passive ROM assessment helped to determine whether movement limitations were due to problems affecting joint structures.

Isometric strength (in kg) of the shoulder flexor, abductor and rotator muscles was measured using a hand-held, digital strain-gauge dynamometer (Microfet, Hoggan Health, UT, USA). The patient was in the supine position, and standard stabilisation (provided by the tester) and test positions were used [28–30]. The dynamometer was held proximal to the epicondyles for the measurement of flexor muscle strength, proximal to the lateral epicondyle for the measurement of abductor muscle strength, and proximal to the wrist for the measurement of internal and external rotator muscle strength. A 'make' test procedure was used, where the subject was asked to ramp up the contraction for approximately 2 seconds and hold the maximum effort against the resistance applied by the therapist for 4 to 5 seconds. Rest periods were provided between the trials. Each muscle action was measured in a position that was unaffected by gravity, while holding the dynamometer perpendicular to the limb.

Hand evaluation

Grip and pinch strength (key pinch and palmar, in kg) were measured using a Jamar dynamometer (J.A. Preston, Grand Rapids, MI, USA) and a pinch gauge (B&L Engineering, Santa Ana, CA, USA), respectively. The subject was seated with their shoulder adducted and in neutral rotation, the elbow flexed at 90° and the forearm in a neutral position [31].

The nine-hole peg test (Sammons Preston, Cedarburg, WI, USA) was used to measure dexterity using standardised methods [11]. The participant placed pegs in nine holes using one hand at a time, and removed them as quickly as possible one at a time. The total time to complete each test was noted.

Limited joint mobility of the hand was quantified via the 'prayer sign'. Subjects' inability to press their palms together completely without a gap remaining between the opposed palms and fingers was termed a 'positive prayer sign' (Fig. 1) [9].

Light touch perception was measured in the peripheral nerve supply of the hand using Semmes Weinstein monofilaments (Tactile sensory evaluator, Baseline, Elmsford, NY,

USA) [20,32,33]. Filaments ranging from 2.83 to 6.65 (0.07 to 330 g force) were applied until they bent and #6.65 was applied just to bending. The smallest perceivable monofilament was noted. The grading for the monofilaments was as follows: intact (2.83), diminished light touch (3.61), diminished protective sensation (4.31), and loss of protective sensation (4.56 to 6.65) [32,33].

Statistical analyses

Statistical analyses were performed using Statistical Package for the Social Sciences Version 19.0 (IBM Corp., Armonk, NY, USA). The alpha level was set at $P < 0.05$. Descriptive statistics [percentages, means, standard deviations, medians, interquartile ranges (IQR) and percent changes] were used to describe outcome measures. There were no significant differences between right and left upper extremity evaluation measures in patients with diabetes; therefore, only data from the right upper extremity were included in the statistical analyses. All data were analysed using the Shapiro–Wilk test for normality, and non-parametric tests were used for representing SPADI scores, internal rotation strength measurements and dexterity measurements. Student's *t*-test and Chi-squared test (for limited joint mobility of the hand) were used to examine group differences in the upper extremity clinical measures, and Pearson's correlation co-efficient was used to examine the relationship between the total SPADI score and upper extremity measures. Further, a hierarchical multiple regression analysis was performed using the total SPADI score as the dependent variable and the shoulder abduction ROM and hand grip strength as predictors. These measures were chosen *a priori* because: (1) abduction ROM provides an indication of one's ability to perform a variety of shoulder movements; and (2) grip strength is often used as a surrogate measure for decreased upper extremity strength and as a predictor of disability [19,34].

Results

Flyer

In total, 236 flyers, containing the SPADI questionnaire and demographic information, were collected from patients with diabetes [median total SPADI score 10.0 (IQR 0.0 to 39.6)]. The median SPADI pain subscore was 16.0 (IQR 0.0 to 48.0) and the median SPADI disability subscore was 5.0 (IQR 0.0 to 31.3). One hundred and thirty-three flyers were collected via post and 103 flyers were collected at the diabetes clinic. The overall response rate to the flyer was 54% (236/439). Subject characteristics are listed in Table 1. Overall, 63% (149/236) of patients with diabetes reported shoulder pain and/or disability [median total SPADI score 28.9 (IQR 12.0 to 53.8)], and 30% (72/236) reported substantial pain and/or disability, operationally defined as a SPADI score of more than 30% [median total SPADI score 53.8 (IQR 40.1 to 66.3)].

Upper extremity evaluation

Subject characteristics of the patients with diabetes and the control group matched for age, weight, height and sex are represented in Table 2. The majority of participants (46/56) reported that they were retired. Furthermore, 40 out of 56 participants said that their

occupation did not involve overhead activities, eight said that their occupation involved overhead activities and eight did not respond to the question.

Shoulder measures—Passive flexion, abduction and external rotation ROM were reduced by 9% to 15% ($P<0.01$) in patients with diabetes compared with the control group {right upper extremity [mean (standard deviation)]—flexion: 154° (25) vs 170° (6); mean difference -16° , 95% CI of the difference -25 to -6 ; abduction: 147° (29) vs 170° (5); mean difference -23° , 95% CI of the difference -33 to -13 ; external rotation: 67° (13) vs 79° (5); mean difference -12° , 95% CI of the difference -17° to -7° } (Table 2). Active flexion, abduction and external rotation ROM were also reduced in patients with diabetes compared with the control group ($P<0.05$) {right upper extremity [mean (standard deviation)]—flexion: 151° (19) vs 165° (7), mean difference -14° , 95% CI of the difference -21 to -7 ; abduction: 153° (19) vs 166° (7), mean difference -13° , 95% CI of the difference -21 to -6 ; external rotation: 59° (11) vs 67° (9), mean difference -8° , 95% CI of the difference -12 to -2 ; $P=0.01$ }. Mean shoulder flexor, and external and internal rotator strength were reduced by 11% to 26% ($P<0.05$; Table 2) in patients with diabetes compared with the control group {right upper extremity [mean (standard deviation)]—shoulder flexor muscle strength: 10.9 (3.9) vs 14.7 (4.2), mean difference -3.8 , 95% CI of the difference -6.0 to -1.5 ; shoulder external rotator muscle strength: 10.8 (3.3) vs 13.1 (3.7), mean difference -2.3 , 95% CI of the difference -4.2 to -0.3 ; shoulder internal rotator muscle strength: 12.1 (3.8) vs 13.1 (3.7), mean difference -1.5 , 95% CI of the difference -3.5 to -0.5 }.

Hand measures—Grip strength and key pinch strength were decreased by 15% and 12% ($P<0.05$), respectively, in patients with diabetes compared with the control group (Table 3) {right hand [mean (standard deviation)] grip strength: 28.4 (9.7) vs 33.4 (10.3), mean difference -5.0 , 95% CI of the difference -10.4 to -0.5 ; key pinch strength: 9.2 (5.4) vs 10.5 (2.3), mean difference -0.9 , 95% CI of the difference -2.1 to -0.3 }. Limited joint mobility of the hand, indicated by the ‘positive’ prayer sign, was more prevalent in patients with diabetes compared with the control group (17/27 vs 4/27, $P=0.006$; Table 3). Peripheral sensation was more frequently impaired in patients with diabetes compared with the control group (26/27 vs 14/27; Table 3).

Relationship between SPADI scores and upper extremity evaluation measures

There was a strong negative correlation between total SPADI score and shoulder ROM measures ($r=-0.42$ to -0.74 , $P<0.05$), and shoulder muscle strength ($r=-0.44$ to -0.63 , $P<0.05$; Table 2) in the patients with diabetes. Sixty-eight percent ($P<0.01$) of the variance in total SPADI score was explained by shoulder abduction ROM (R^2 change=0.55, $P<0.001$) and grip strength (R^2 change=0.13, $P=0.003$).

Discussion

Sixty-three percent of patients with diabetes reported shoulder pain and/or disability, and 31% of patients with diabetes had substantial pain and/or disability, defined in this study as a total SPADI score of more than 30%. Upper extremity impairments in this sample of patients with diabetes attending an outpatient diabetes centre were common, severe, and

related to complaints of pain and disability (Tables 1 to 3). Shoulder ROM, especially external rotation and abduction, and strength were reduced (8 to 25%) and negatively correlated ($r=-0.42$ to -0.68) with SPADI score, indicating the close relationship between limited joint mobility of the shoulder, strength and upper extremity function.

This is the first study to comprehensively report shoulder and hand impairments, and their relationship with upper extremity function in patients with diabetes. Shinabarger [14] measured shoulder active ROM in a small group of patients with type 2 diabetes ($n=9$), and Abate *et al.* [16] measured passive ROM for flexion and abduction ROM, and reported a 2 to 14% reduction in ROM in patients with diabetes compared with those without diabetes. Adequate shoulder ROM, especially external rotation and abduction, and strength are particularly important for completing tasks of daily living such as reaching an overhead shelf, grooming and self-care. Interestingly, in a subgroup of patients with diabetes who had a SPADI score of 0% ($n=5$), shoulder ROM and strength were reduced by 8 to 10% and 5 to 13%, respectively, compared with controls with similar SPADI scores, suggesting that early losses may not be recognised by the patient.

Hand strength, mobility and sensation were decreased in patients with diabetes compared with the control group, contributing to the global upper extremity dysfunction in patients with diabetes. Savas *et al.* noted similar decreases in grip strength (16%) and key pinch strength (9%) in patients with diabetes compared with those without diabetes [17]. Significant differences in grip strength and sensation in the hand have also been recorded in other studies [11,18–20,35]. Individuals with diminished protective sensation may have decreased hand function, leading to difficulty in manipulation of small objects and a tendency to drop objects [11,32]. Hand dexterity, although reduced, was not significantly different between the two groups in this study. Redmond *et al.* reported that 38% of the variance in Disability of Arm Shoulder and Hand score was explained by grip strength, dexterity and BMI measures [11]. In the present study, 68% ($P<0.01$) of the variance in total SPADI score was explained by abduction ROM and grip strength, verifying that measurable upper extremity impairments are related to complaints of pain and/or disability. Previous studies have failed to report the combined influence of these shoulder and hand impairments on overall upper extremity function.

The results from this study support the hypothesis that shoulder and hand impairments impact upper extremity function in patients with type 2 diabetes. Future studies in patients with diabetes should focus on studying the shoulder and hand as one functional unit. This study characterised insidious upper extremity impairments in patients with diabetes, and these results may help to develop appropriate treatment strategies for these individuals. If impairments are identified at an early stage, simple exercises that focus on improving upper extremity ROM (especially external rotation and elevation, and strength) may be administered to minimise or prevent further detrimental changes in patients with diabetes. In one of the few prospective studies on shoulder disorders in diabetes, Laslett *et al.* reported that 45% of patients with diabetes had shoulder pain and/or disability, as measured via the SPADI [5]. In a 12-month follow-up, 25% of individuals who reported no pain and/or disability at baseline developed clinically significant pain or disability (10% point change on the SPADI). Additionally, of the patients with pre-existing pain and/or disability, 50%

developed clinically significant worsening of pain and/or disability. It is postulated that diabetes causes loss of ROM and strength that may hit a 'threshold' leading to severe upper extremity limitations and disability. Further research is needed to understand the factors that may be associated with the progression of upper extremity impairments in patients with diabetes, and to determine if exercise can be used to help prevent the problems.

This study adds to the growing body of research describing limited joint mobility in the upper and lower extremities of patients with diabetes [16,36,37]. The underlying mechanisms that lead to these systemic musculoskeletal changes need further investigation. The primary mechanism for limited joint mobility is believed to be the condensation of glucose and metabolic intermediates to form advanced glycation end-products (AGEs) [12,38]. AGEs accumulate in tissues with low protein turnover such as skin and tendons, and lead to cross-links making the tissues thicker, stiffer and weaker, and therefore, more prone to injury [39]. These structural changes may affect joint movement. Although detailed kinematic studies have been performed on the shoulders of patients with adhesive capsulitis [40], additional research is needed to understand the three-dimensional glenohumeral and scapulothoracic ROM deficits unique to diabetes and limited joint mobility. Investigating the relationships between AGEs, structural changes and upper extremity movement impairments will provide insights into the upper extremity musculoskeletal problems in patients with diabetes. A better understanding of the physiological and movement-related factors associated with diabetic musculoskeletal problems may lead to enhanced treatment strategies (i.e. exercise or pharmacological) to manage or even prevent the problems.

Study limitations

This study sought to collect data from a representative sample of patients with diabetes attending an outpatient clinic, but there may have been sampling bias between the respondents and non-respondents in the questionnaires. To minimise this bias, a cover letter was included that encouraged the participant to respond even if they did not have pain/disability, and SPADI information was collected at the diabetes clinic for patients with diabetes, not selected by their pain/disability levels. While upper extremity impairments were evaluated in patients with diabetes with varying levels of pain and/or disability, there is also the possibility of sampling bias. Patients with diabetes and controls were matched for age, weight, height, BMI, sex and handedness, which allowed group differences (patients with diabetes vs controls) in upper extremity function to be examined with greater confidence. It is acknowledged that the physical therapist who took the clinical measurements was not blinded to group allocation, which may have led to bias. Lastly, as this was a cross-sectional study, the authors cannot comment on the temporal relationship between the development and progression of upper extremity problems. Additional research on a large sample of patients with diabetes is needed to determine more clearly if the insidious loss of shoulder ROM is a precursor to severe shoulder disability.

Conclusions

A substantial majority (63%) of patients with diabetes in this study reported shoulder pain and/or disability. Compared with the control group, patients with diabetes had considerably

limited joint mobility and strength deficits in the shoulder and hand, and decreased sensation. Complaints of upper extremity functional deficits, and pain and/or disability were highly correlated with shoulder and hand ROM, especially shoulder external rotation and abduction, and strength deficits. These impairments, which may be overlooked in the rehabilitation clinic setting, are related to functional deficits and may lead to difficulty in performing daily life activities. Further studies are needed to better characterise upper extremity movement impairments in diabetes, and the pathological mechanisms and methods for prevention and treatment.

Acknowledgments

The authors wish to thank Dr. Catherine E. Lang for contributing to the study design and methods, and Ms. Lori Buechler for helping with data collection.

Funding: Subject recruitment for this study was supported by the Washington University School of Medicine Diabetes Research and Training Center (NIH 5 P60 DK 20579).

References

1. Ramchurn N, Mashamba C, Leitch E, Arutchelvam V, Narayanan K, Weaver J, et al. Upper limb musculoskeletal abnormalities and poor metabolic control in diabetes. *Eur J Int Med.* 2009; 20:718–21.
2. Arkkila PE, Gautier JF. Musculoskeletal disorders in diabetes mellitus: an update. *Best Pract Res Clin Rheumatol.* 2003; 17:945–70. [PubMed: 15123045]
3. Arkkila, P. Academic thesis. Vol. 244. *Annales Universitatis Turkuensis*; 1996. Hand and shoulder abnormalities in diabetic patients: association with diabetes-related complications and diabetes; p. 1-136.
4. Cagliero E, Apruzzese W, Perlmuter GS, Nathan DM. Musculoskeletal disorders of the hand and shoulder in patients with diabetes mellitus. *Am J Med.* 2002; 112:487–90. [PubMed: 11959060]
5. Laslett LL, Burnet SP, Redmond CL, McNeil JD. Predictors of shoulder pain and shoulder disability after one year in diabetic outpatients. *Rheumatology (Oxford).* 2008; 47:1583–6. [PubMed: 18713767]
6. Smith LL, Burnet SP, McNeil JD. Musculoskeletal manifestations of diabetes mellitus. *Br J Sports Med.* 2003; 37:30–5. [PubMed: 12547740]
7. Cole A, Gill TK, Shanahan EM, Phillips P, Taylor AW, Hill CL. Is diabetes associated with shoulder pain or stiffness? Results from a population based study. *J Rheumatol.* 2009; 36:371–7. [PubMed: 19012358]
8. Pal B, Anderson J, Dick WC, Griffiths ID. Limitation of joint mobility and shoulder capsulitis in insulin and non insulin dependent diabetes mellitus. *Br J Rheumatol.* 1986; 25:147–51. [PubMed: 3708230]
9. Rosenbloom AL, Silverstein JH, Lezotte DC, Richardson K, McCallum M. Limited joint mobility in childhood diabetes indicates increased risk for microvascular disease. *N Engl J Med.* 305:191–4. [PubMed: 7242598]
10. Gamstedt A, Holm-Glad J, Ohlson CG, Sundstrom M. Hand abnormalities are strongly associated with the duration of diabetes mellitus. *J Intern Med.* 1993; 234:189. [PubMed: 8340742]
11. Redmond CL, Bain GI, Laslett LL, McNeil JD. Hand syndromes associated with diabetes: impairments and obesity predict disability. *J Rheumatol.* 2009; 36:2766–71. [PubMed: 19884270]
12. Silverstein JH, Gordon G, Pollock BH, Rosenbloom AL. Long-term glycemic control influences the onset of limited joint mobility in type 1 diabetes. *J Pediatr.* 1998; 132:944–7. [PubMed: 9627583]
13. Starkman HS, Gleason RE, Rand LI, Miller DE, Soeldner JS. Limited joint mobility (LJM) of the hand in patients with diabetes mellitus: relation to chronic complications. *Ann Rheum Dis.* 1986; 45:130–5. [PubMed: 3947142]

14. Shinabarger NI. Limited joint mobility in adults with diabetes mellitus. *Phys Ther.* 1987; 67:215–8. [PubMed: 3809247]
15. Schulte L, Roberts MS, Zimmerman C, Ketler J, Simon LS. A quantitative assessment of limited joint mobility in patients with diabetes. *Goniometric analysis of upper extremity passive range of motion. Arthritis Rheum.* 1993; 36:1429–43. [PubMed: 8216403]
16. Abate M, Schiavone C, Pelotti P, Salini V. Limited joint mobility (LJM) in elderly subjects with type II diabetes mellitus. *Arch Gerontol Geriatr.* 2011; 53:135–40. [PubMed: 20940076]
17. Savas S, Koroglu BK, Koyuncuoglu HR, Uzar E, Celik H, Tamer NM. The effects of the diabetes related soft tissue hand lesions and the reduced hand strength on functional disability of hand in type 2 diabetic patients. *Diabetes Res Clin Pract.* 2007; 77:77–83. [PubMed: 17141353]
18. Cetinus E, Buyukbese MA, Uzel M, Ekerbicer H, Karaoguz A. Hand grip strength in patients with type 2 diabetes mellitus. *Diabetes Res Clin Pract.* 2005; 70:278–86. [PubMed: 15878215]
19. Park SW, Goodpaster BH, Strotmeyer ES, de Rekeneire N, Harris TB, Schwartz AV, et al. Decreased muscle strength and quality in older adults with type 2 diabetes: the Health, Aging, and Body Composition Study. *Diabetes.* 2006; 55:1813–8. [PubMed: 16731847]
20. Redmond CL, Bain GI, Laslett LL, McNeil JD. Deteriorating tactile sensation in patients with hand syndromes associated with diabetes: a two-year observational study. *J Diabet Complicat.* 2012; 26:313–8.
21. Roach KE, Budiman-Mak E, Songsiridej N, Lertratanakul Y. Development of a shoulder pain and disability index. *Arthritis Care Res.* 1991; 4:143–9. [PubMed: 11188601]
22. MacDermid JC, Solomon P, Prkachin K. The shoulder pain and disability index demonstrates factor, construct and longitudinal validity. *BMC Musculoskelet Disord.* 2006; 7:12. [PubMed: 16472394]
23. Roy SJ, MacDermid JC, Woodhouse LJ. Measuring shoulder function: a systematic review of four questionnaires. *Arthritis Rheum.* 2009; 61:623–32. [PubMed: 19405008]
24. Sabari JS, Maltzev I, Lubarsky D, Liskay E, Homel P. Goniometric assessment of shoulder range of motion: comparison of testing in supine and sitting positions. *Arch Phys Med Rehabil.* 1998; 79:647–51. [PubMed: 9630143]
25. Hayes K, Walton JR, Szomor ZR, Murrell GA. Reliability of five methods for assessing shoulder range of motion. *Aust J Physiother.* 2001; 47:289–94. [PubMed: 11722295]
26. Riddle DL, Rothstein JM, Lamb RL. Goniometric reliability in a clinical setting. *Shoulder measurements. Phys Ther.* 1987; 67:668–73. [PubMed: 3575423]
27. Trombly, Randomski. *Occupational therapy for physical dysfunction.* 6. 2008. p. 104-5.
28. Andrews AW, Thomas MW, Bohannon RW. Normative values for isometric muscle force measurements obtained with hand-held dynamometers. *Phys Ther.* 1996; 76:248–59. [PubMed: 8602410]
29. Hayes K, Walton JR, Szomor ZL, Murrell GA. Reliability of 3 methods for assessing shoulder strength. *J Shoulder Elbow Surg.* 2002; 11:33–9. [PubMed: 11845146]
30. Bohannon RW. Test retest reliability of hand-held dynamometry during a single session of strength assessment. *Phys Ther.* 1986; 66:206–9. [PubMed: 3945674]
31. Mathiowetz V, Kashman N, Volland G, Weber K, Dowe M, Rogers S. Grip and pinch strength: normative data for adults. *Arch Phys Med Rehabil.* 1985; 66:69–72. [PubMed: 3970660]
32. Bell-Krotoski, JA. Sensibility testing with the Semmes–Weinstein monofilaments. In: Mackin, EJ.; Callahan, AD.; Skirven, TM.; Schneider, LH.; Osterman, AL., editors. *Rehabilitation of the hand and upper extremity.* 5. Vol. 1. St Louis: Mosby; 2002. p. 194-213.
33. Von Prince K, Butler B. Measuring sensory function of the hand in peripheral nerve injuries. *Am J Occup Ther.* 1967; 21:385–95. [PubMed: 6083106]
34. Bohannon RW. Hand-grip dynamometry predicts future outcomes in aging adults. *J Geriatr Phys Ther.* 2008; 31:3–10. [PubMed: 18489802]
35. Cederlund RI, Thomsen N, Thrainsdottir S, Eriksson KF, Sundkvist G, Dahlin LB. Hand disorders, hand function, and activities of daily living in elderly men with type 2 diabetes. *J Diabet Complicat.* 2009; 23:32–9.

36. Mueller MJ, Diamond JE, Delitto A, Sinacore DR. Insensitivity, limited joint mobility, and plantar ulcers in patients with diabetes mellitus. *Phys Ther.* 1989; 69:453–9. [PubMed: 2727069]
37. Roquelaure Y, Ha C, Rouillon C, Fouquet N, Leclerc A, Descatha A, et al. Members of Occupational Health Services of the Pays de la Loire Region. Risk factors for upper-extremity musculoskeletal disorders in the working population. *Arthritis Rheum.* 2009; 61:1425–34. [PubMed: 19790112]
38. Brownlee M. Glycation products and the pathogenesis of diabetic complications. *Diabetes Care.* 1992; 15:1835–43. [PubMed: 1464241]
39. Reddy GK. Cross-linking in collagen by nonenzymatic glycation increases the matrix stiffness in rabbit Achilles tendon. *Exp Diabetes Res.* 2004; 5:143–53. [PubMed: 15203885]
40. Rundquist PJ, Anderson DD, Guanche CA, Ludewig PM. Shoulder kinematics in subjects with frozen shoulder. *Arch Phys Med Rehabil.* 2003; 84:1473–9. [PubMed: 14586914]

Fig. 1.
The 'positive prayer sign' is the inability to press the palms together completely without a gap remaining between opposed palms and fingers.

Table 1

Demographic and Shoulder Pain and Disability Index (SPADI) information

Total survey flyers	236
Posted	133
Completed at diabetes clinic	103
Age (years)	61.4 (11.9)
Body mass index (kg/m ²)	31.7 (6.9)
Male	47% (112)
Type 2 diabetes	72.9 % (172)
Duration of diagnosed diabetes (years)	16.4 (12.1)
HbA _{1c} (%)	7.37 (1.3)
Total SPADI score ^a	10.0 (IQR 0.0 to 39.6)
SPADI not equal to 0%	63% (149/236)
SPADI over 30%	31% (72/236)

IQR, interquartile range.

Data represented as mean (standard deviation) or % (*n*) unless otherwise indicated.^a Data represented as median and interquartile range.

Table 2

Subject characteristics and shoulder evaluation measures

Measure (units)	Patients with diabetes	Controls	P-value ^a	Correlation with total SPADI scores ^b
Number of subjects	27	27		
Age (years)	65.7(8.9)	64.4(8.7)	0.64	
Weight (kg)	101.1 (21.2)	98.1(16.4)	0.99	
Height (m)	1.7 (0.09)	1.7 (0.10)	0.93	
Body mass index (kg/m ²)	33.2 (5.5)	33.3 (6.0)	0.93	
Sex (male/female)	17/10	17/10		
Handedness (right/left)	26/1	26/1		
SPADI score (%)	37.1 (27.9)	0		
Passive ROM (degrees)				
Flexion				
Right	154 (25)	170 (6)	0.001	-0.68 [†]
Left	149 (30)	170 (5)		
Abduction				
Right	147 (26)	170 (5)	0.001	-0.74 [†]
Left	141 (29)	170 (6)		
External rotation				
Right	67 (13)	79 (5)	0.001	-0.51 [†]
Left	61 (20)	76 (5)		
Internal rotation ^c				
Right	76 (71–81)	80 (77–84)	0.10	-0.42 [*]
Left	77 (71–81)	81 (79–85)		
Active ROM (degrees)				
Flexion				
Right	151 (19)	165 (7)	0.001	-0.41 [*]
Left	145 (24)	164 (7)		
Abduction				
Right	153 (19)	166 (7)	0.001	-0.60 [†]
Left	141 (30)	164 (7)		
External rotation				
Right	59 (11)	67 (9)	0.011	-0.22
Left	55 (13)	65 (9)		
Strength (kg)				
Flexors				
Right	10.9 (3.9)	14.7 (4.2)	0.001	-0.44 [*]
Left	9.8 (3.8)	13.9 (4.3)		

Measure (units)	Patients with diabetes	Controls	<i>P</i> -value ^a	Correlation with total SPADI scores ^b
Abductors				
Right	9.1 (3.8)	10.5 (2.4)	0.15	-0.56 [†]
Left	8.5 (2.8)	9.7 (2.3)		
External rotators				
Right	10.8 (3.3)	13.1 (3.7)	0.02	-0.51 [†]
Left	9.5 (3.8)	11.1 (2.8)		
Internal rotators				
Right	12.1 (3.8)	13.6 (3.5)	0.048	-0.63 [†]
Left	11.3 (4.8)	14.5 (3.3)		

SPADI, Shoulder Pain and Disability Index; ROM, range of motion.

Data represented as mean (standard deviation) unless otherwise indicated.

^a *P* values were determined using independent sample Student's *t*-test.

^b Correlation between total SPADI score and shoulder ROM and strength measures was determined using Pearson's correlation coefficient (*n*=29);

* *P*<0.05;

[†] *P*<0.01.

^c Non-parametric tests were used: Mann-Whitney U-test and Spearman's correlation. Data represented as median and interquartile range.

Table 3

Hand evaluation measures

Measure (units)	Patients with diabetes (<i>n</i> =27)	Controls (<i>n</i> =27)	<i>P</i> -value ^{<i>a</i>}	Correlation with total SPADI scores ^{<i>b</i>}
Grip strength (kg)				
Right	28.4 (9.7)	33.4 (10.3)	0.045	−0.28
Left	27.1 (10.0)	32.3 (9.5)		
Key pinch strength (kg)				
Right	9.2 (5.4)	10.5 (2.3)	0.04	−0.28
Left	7.7 (2.5)	8.6 (2.0)		
Palmar pinch strength (kg)				
Right	6.7 (2.2)	7.3 (1.9)	0.32	0.10
Left	6.7 (2.6)	7.3 (2.5)		
Nine-hole peg test (seconds) ^{<i>c</i>}				
Right	23.8 (3.7)	22.4 (3.4)	0.056	0.14
Left	25.0 (4.7)	22.9 (3.0)		
Hand sensation (<i>n</i>):				
Intact	1	13		
Diminished light touch	17	13		
Diminished protective sensation	8	1		
Loss of protective sensation	1	0		
Prayer sign (<i>n</i>)				
Negative	10	23	0.006 ^{<i>d</i>}	
Positive	17	4		

SPADI, Shoulder Pain and Disability Index; ROM, range of motion.

Data represented as mean (standard deviation) unless otherwise indicated.

^{*a*}Determined using independent sample Student's *t*-test.

^{*b*}Correlation between total SPADI score and shoulder ROM and strength measures was determined using Pearson's correlation coefficient (*n*=29).

^{*c*}Non-parametric tests were used: Mann–Whitney *U*-test and Spearman's correlation.

^{*d*}Significance determined by Chi-squared test.